OUTLINE OF AQUACULTURE

"Red Sea Bream Culture"

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Edited by

Kunihiko FUKUSHO, Dr.

National Research Institute of

Aquaculture

Fisheries Agency

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RED SEA BREAM CULTURE

K.FUKUSHO

INTRODUCTION AND BACKGROUND

Red sea bream, *Pagrus major*, has been called the king of fish in Japan. Traditionally, Japanese people have thought highly of red sea bream due to its beautiful oval shape and red coloration as well as the good taste (Fig. 1). For almost all kinds of fish, market price usually varies among different localities, but red sea bream is unique in the sense that it has the same market price throughout Japan. This is indicative of the special importance of red sea bream. Also, red sea bream has been used as a symbol of celebration at various kinds of religious and traditional events as well as for luxury food.

The maximum size of wild red sea bream is approximately 90 cm and nearly 9 kg at an age presumed to be almost 30–40 years. Red sea bream occurs in almost all the seas of Japan, Korea, China, Taiwan, and southeast Asia[1,2]. Its habitat is in coastal areas of 30–150m depth but it migrates into shallower areas to spawn. Wild red sea bream feed on molluscs, crustaceans, echinoderms, and small fish. The reproductive minimum size of wild red sea bream is 36 cm and 750g (4–5 years old), but 23–26 cm and 320–340g is common in cultured fish (2–3 years old). The cultured male fish matures at a size of 22 cm (2 years)[3–5]. The spawning season varies among localities, but is approximately April to June. The preferred temperature for spawning is 18–20°C.

Red sea bream culture was initiated in 1965 using wild juveniles, and it is mainly cultured in the south-western part of Japan, Nagasaki, Mie, Kumamoto, Ehime, Wakayama, Kochi, Oita, and Kagoshima prefectures (Fig. 2). Total production has been increasing year by year over the past ten years (4,303 tons in 1975 up to 37,731t in 1987) (Table 1). By contrast, production by fisheries has been decreasing (20,876t in 1972 to 13,704t in 1985). This production of red sea bream by culture is second to yellowtail, *Seriola quinqueradiata* (approximately 160,000t), among nearly 30 species of marine finfish cultured in Japan.

Demand for red sea bream has been high since long ago in Japan, but the actual industry of red sea bream culture had not been developed until recently for the following reasons: 1) the body coloration of red sea bream became black during rearing, and the commercial value was significantly reduced, 2) red sea bream was expensive, and as a luxury fish the amount of consumption was small, 3) red sea bream required 4–5 years to reach commercial size judging from the wild fish condition, 4) supply of juveniles was not stable, 5) the present net cage system for culture was not developed at that time.

The reason why red sea bream culture started around 1965 is as follows: 1) the Japanese economy was highly developed and actual income had been increasing over the years; therefore, demands for expensive and luxury fish increased in Japan, 2) The technology to supply juveniles by artificial production was developed, 3) The impact of yellowtail culture industry which has been successful as the first domesticated marine finfish in Japan, 4) The development of formula feed, 5) confirmation of faster growth rate than that of wild fish (2–3 years to reach marketabale size, 1 kg).

Several textbooks and papers on red sea bream culture are useful to provide more precise information, and they are listed in the bibliography.

Table 1. Statistics of red sea bream, *Pagrus major* culture in Japan (After the annual statistics of fishery and aquaculture, by the Ministry of Agrl., Forest., and Fish., Japan)

Year	Production (t)	Introduction of juveniles into nets (x 1000)	Number of farmers	Number of net cages
1977	(8345)	21577	1781	7869
78	(11315)	29364	2069	9128
79	(12492)	28231	2413	10862
80	(14973)	36084	2689	14234
81	(18243)	34007	2831	15499
82	(20648)	42052	2940	15644
83	24811	47512	2924	17228
84	25934	55182	2894	17698
85	28322	56230	3014	19274
86	33258	63153	2946	19360
87	37731	64599	2909	19451

Numerals in parentheses show the production including the other related species.

BROODSTOCK AND MATURATION

The establishment of a method for collecting fertilized eggs by natural spawning of cultured breeder fish is one of the factors which permitted mass production of red sea bream. For spawning, initially a hormone drug was injected into wild fish. In 1968, natural spawning in tanks was observed. Since then, natural spawning in tanks has been attempted, gradually coming to a practical mass production method at present. But, induced spawning is still used for various kinds of experiments such as chromosome manipulation, cross breeding and gamete preservation.

Ordinarily, brood stock are kept in net cages hanging from rafts in inlets (Fig. 3) and at the spawning season, breeders are moved to spawning tanks on land for natural spawning. Also, land based tanks are used to maintain the brood stock (Fig. 4). For feeds, sardine, mackerel, sand eel, saury, shrimps, and commercial feed (pellets) are mainly used. Some farming stations use feeds of their own composition (e.g. 40% minced fish meat, 30% krill, 30% mixed fish meal, vitamin, etc., limiting the feed to krill at the spawning season). In any case, it has been empirically demonstrated that feeding breeders with krill, exclusively or in a mixture, is effective in obtaining a stable supply of quality eggs.

To investigate the effect of feeds on spawning of red sea bream, a series of studies have recently been made, with the following conclusions: 1) as protein source of brood stock feed, cuttle fish meal is better than white fish meal, 2) feeding breeders with krill increases the amount of buoyant eggs, hatching rates and numbers of normal larvae, and the quality of the feed given directly before spawning has a significant effect on red sea bream eggs, 3) the proper protein content in feeds is estimated to be nearly 45%, 4) differences in nutritional composition of brood stock feed, even for short feeding periods, are remarkably reflected in the chemical composition of the egg, i.e., the ω3HUFA content in eggs from ω3HUFA-rich feed is high, egg quality from feed without EFA is very poor, adding corn oil causes the 18:2w6 ration to increase greatly.

Ovarian eggs are categorized into the four types based on the degree of maturation, and these types coincide with the four histological stages of maturation, respectively. Oogenesis starts in early autumn and the ovary gradually matures over the winter. The ovary rapidly matures in early April, and the breeder starts to spawn. In June, post ovulatory folicle and atretic eggs are found in the ovary, and only previtellogenic oocytes are found in August. In contrast, spermatogenesis occurs for a fairly long period (February to June).

HATCHERY TECHNIQUE

To collect fertilized eggs, breeders are moved to land based concrete tanks (spawning tanks) for natural spawning (Fig. 5). This transfer is generally carried out when breeders start spawning in net cages. Spawning tanks are rectangular or round, one to two meters depth in, with a capacity ranging from 50 to 100 m^3. Fertilized eggs are collected by collecting the overflow or siphoning into outside nets (made of gauze cloth, meshes 200 to 400 μm) (Fig. 6). The male to female ratio of breeders is usually one to one and spawners are three to twelve years old (mainly three to four years old). The spawning season varies according to the locality, starting between late March and early April in coastal areas on the Pacific Ocean, and late April and in mid and late May in coastal areas on the Japan Sea. Water temperature at the start of spawning varies between 11.1–17.2°C, with most spawning occurring around 15°C. Spawning ends between late June and early July when the water temperature is around 25°C. Maximum performance in spawning occurs at 18–20°C. One breeder spawns approximately two to three million eggs during the spawning season (60–80 days).

The collected eggs are put in a small tank, 30 to 50ℓ, and only buoyant eggs are placed in the incubation nets (0.2–0.3 million eggs per the net, 1 x 1 x 0.5m). The mesh of the net is approximately 300 μm, and several nets are hung in indoor concrete tanks with a water exchange of 10–12 times per day. Air is supplied at 200 mℓ/min, by air stone in each net. It is usual to eliminate the sunken eggs, weigh the buoyant eggs and introduce them directly into larval rearing tanks. The number of the eggs is estimated on the basis of standard rate of 1,800 eggs per g of fertilized eggs. The hatching ratio is generally above 90%. The ratios of buoyant eggs, hatching, and normal eggs are high since the fertilized eggs at the peaks of spawning are used selectively.

Spawned eggs of red sea beam are round, almost transparent, and pelagic. The diameter of the egg is 0.85–1.10 mm, with an oil globule (0.22–0.25 in diameter). It takes 58 hours for hatching of eggs with a temperature 15.2–16.8°C. Eggs stop their development at 10°C, and show abnormal cleavage and development at 30°C.

ROTIFER CULTURE

Twenty-five years have passed since the introduction of the rotifer *Brachionus plicatilis* O.F.Muller as a food organism for the fry production of marine finfish. During this period, mass culture techniques for this rotifer have been greatly developed e.g., 1.2×10^{12} rotifers (ca. 2.5 ton) produced 6.3×10^{6} fish juveniles (red sea bream and porgy *Acanthopagrus schlegeli*, 12.1–16.0 mm in TL) in a hatchery within a three month period.

There are two strains (S-type and L-type) of rotifers being cultured nearly all over Japan. S-type rotifer (small, 150 μm in lorica length) tolerate high water temperature and is characterized by a round lorica with pointed anterior spines. L-type rotifer (large, 250 μm) tolerate low water temperature and is characterized by a slender lorica with obtuse anterior spines. Recent studies have shown that S and L-type rotifers are different genetic strains. Taxonomically, they are classified as sub-species; *B. plicatilis hepatomus* (L-type) and *B. plicatilis rotundiformis* (S-type), respectively.

The actual methods for mass culture being currently employed in Japan can be categorized by tank capacity (volume of water) and method of harvest: 1) production in large tanks (10–100 m^3) with partial or total harvest, 2) production in small tanks (0.5–1.0 m^3) with total harvest, 3) production in canvas tanks (5–7 m^3) with total or partial harvest, hanging from rafts in calm bays, 4) commercial small scale production with photosynthetic bacteria used as a diet. Diets for the mass culture by the various methods are, *Chlorella*, baker's yeast, baker's yeast and *Chlorella* combined, w-yeast, or w-yeast and *Chlorella* combined.

The nutritional value of rotifers fed with the various feeds mentioned above has been tested in recent works. The rotifers cultured with marine *Chlorella* generally have a high dietary value mainly to the high levels of highly unsaturated fatty acids (HUFA) derived from *Chlorella*, especially eicosapenoic acid (20:5w3). However, a stable *Chlorella* supply is difficult to obtain in terms of quantity and punctuality, especially under mass culture conditions. Therefore, a special yeast (w-yeast) was developed and is now being used commonly. *Chlorella* has been recently reevaluated as rotifer diet since w-yeast is a fairly expensive diet and it presents problems of water quality control. Rotifers being cultivated with baker's yeast lack HUFA and are usually enriched by *Chlorella* water or a special oil prior to feeding to fish larvae. The treatment for enrichment is quite effective even with small amounts of *Chlorella* water compared with the culture of rotifer fed with *Chlorella* alone. It takes 12–24 hours for enrichment to occur (e.g., 5×10^{8} rotifers in 1 m^3 tank with $2–3 \times 10^{7}$ cells/mℓ *Chlorella* water). The marine *Chlorella* has been identified as *Nannochloropsis oculata* by the recent studies.

A minute alga *Tetraselmis tetrathele* has been recently introduced as a new feed for rotifer culture and is already used with *Nannochloropsis*. This new alga multiplies well with the same fertilizers used for *Nannochloropsis* culture and is remarkably tolerant to high water temperature when *Nannochloropsis* tends to decrease in its density. Therefore, *T. tetrathele* might be an effective substitute diet of *Nannochloropsis* during the summer season in Japan.

NURSERY AND TRANSITION TO NATURAL CONDITIONS

Newly hatched larvae of red sea bream are 2.0–2.3 mm in total length. The larva grow fast to about 3.2 mm in TL. by day 3–5 without any food, but being supported by nutrient yolk. The larvae complete the basic development of mouth and digestive organs and start to feed at the size of 3.2 mm in TL. Development of larvae and juveniles is shown in Fig. 7. The relationship between fork length and developmental stage in red sea bream is shown in *Table 2*[9]. It takes nearly 40–50 days to raise to the size (25 mm) of fry for mariculture in net cage.

Table 2. Relationship between the fork length and the developmental stage in red sea bream (Kitajima 1978).

Fork length (mm)	Developmental stage
2.3 – 3.2	prelarva
6.0 – 10.0	postlarva (II)
10.0 – 20.0	juvenile (I)
20.0 – 40.0	juvenile (II)
40.0 – 90.0	young
90.0 – 230	inmature
230 >	adult

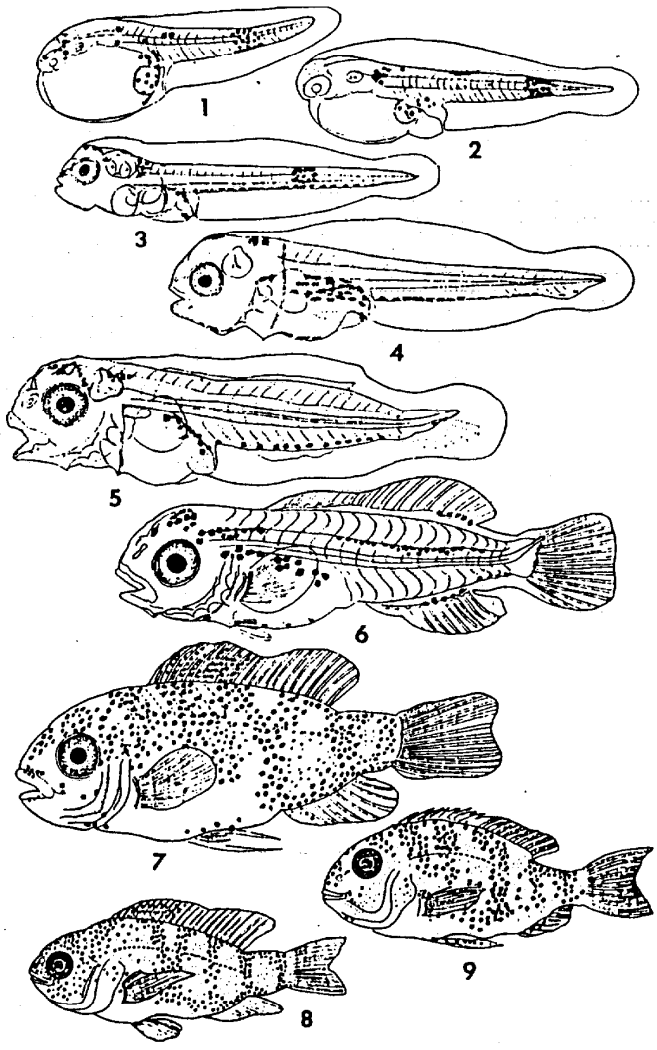

Fig. 7. Development of larvae and juveniles of red sea bream (Fukuhara, 1970).

Fry production can be divided into primary and secondary phases, that is, rearing of the larvae (3 to 10–12 mm) and rearing of the juveniles (12 to 25 mm). From a different angle, the primary phase is rearing with zooplankton (mainly the rotifer, *Brachionus plicatilis*) in land based tanks and the secondary phase is that with minced fish meat in net cages hanging from rafts. For rearing of the larvae, high-density culture in smaller tanks (1–5 m^3) was initially the major technique but today, rearing using large tanks (50 to 100 m^3) is most common. This is for the following reasons: 1) stable supplies of large quantities of the rotifer are now possible, 2) water quality becomes more stable in larger water tanks than in small ones, 3) large water tanks facilitate mechanization to save labor. Mass production centers are increasingly promoting automation of rearing equipment.

For larval rearing (primary rearing), the depth of tanks varies from 1 to 2.5 m. Most of the rearing tanks are rectangular, followed by circular as the most next common shape (Fig. 8). The densities of the newly hatched larvae range from 12,000 to 72,000 fish per m^3 and survival ratios vary with facilities. Water supply to the larval rearing tank per day is 0.1–0.2 times the tank volume at the start of rearing, but the exchange rate increases along with the growth, to 5–10 times the tank volume at the termination of the rearing. Control of illumination is not necessary if the larval rearing tank is indoors, but the tanks should be covered by black cloth to reduce illumination (less than 10,000 to 20,000 lux) in case of outdoor conditions. Facilities having high production techniques show stable survival rates, of 40–50% for fish 12 to 13 mm.

Rearing of the juveniles (secondary rearing) in some cases is conducted in land based tanks. But, most mass production facilities transfer the juveniles to net cages and rear them. The net cage is made of knotless nets 0.5 to 7.0 mm mesh. The net cage capacity varies, the standard being 45 m^3 (4 x 4 x 3m). The density is nearly 1,000 to 2,000 fish per m^3. The juveniles are fed with minced fish meat. During the intitial feeding adjustment period, most mass production facilities mix food items (e.g. sand eel, short neck clam, and krills) at equal ratio. After the juveniles have begun to feed completely, they are fed only with fish meat, occasionally together with vitamins. Net cages are often replaced with clean ones (once a week). The survival rate for the rearing of the juveniles is nearly 50%.

Earlier among hatchery-reared red sea bream, lordosis occurred at a high incidence. This led to extensive studies to investigate the cause of this disease by examining various aspects such as the larval rearing environment, nutritive values of initial feed, and genetics. As a result, it was found that lordosis (the back bone becoming curved in V-shape) was caused and was closely related to the incomplete development of the swim bladder. If the development of the swim bladder was prevented from passing through the physostomous stage to the physoclistous stage, the specific gravity of the fish increased, causing the fish to exhibit an abnormal swimming position because of insufficient buoyancy, resulting in lordosis in the fish. It was also found that development and inflation of the swim bladder was promoted by the behavior of larva (5 to 6 days old) in swallowing small air bubbles near the water surface. Air bubbles passed through the esophagus into the pneumatic duct help the cavity of the swim bladder to expand. This function caused the swim bladder to develop from the physostomous stage to the physoclistous one. Thus, the mechanism of lordosis was clarified and today, with a preventive method using proper control of the rearing environment, lordotic seeds are rare. Effective methods for preventing lordosis include the following: 1) adequate aeration (50 to 100 mℓ/min/m^3), 2) cleaning of the water surface to allow for air to dissolve into water (Fig. 9), 3) sprinkling of adequate water over the water surface, 4) mild fry population density (10,000 to 20,000/m^3). 5) intitially giving nutritious feed, and 6) selection of larvae with a well-developed swim baldder.

Before stocking juveniles to the coastal areas under sea ranching programs, intermediate culture of juveniles is required for acclimation to wild conditions, but the technology has not been well developed. The present method is to rear juveniles until a size large enough for release[7]. The size of juveniles in the beginning of the intermediate culture varies with the fish farming centers. The size will range from nearly 10 mm in case of secondary rearing to 25 mm for use in fish culture. There are several methods to conduct the intermediate rearing, but raising in net cages is most common. The volume of the net cage varies by location but 5 x 5 x 4 mis a standard size. The net has to be changed once every 7 to 10 days, with a larger mesh net each time. This net change requires time and labor. On the other hand, the net enclosures, in small inlet and bays require less labor but suffer from the loss of juveniles due to escape from the net enclosure or predation by birds. The intermediate culture using land based tanks requires energy inputs to pump the sea water and the rearing cost is therefore expensive, although the method is intensive and systematic.

For stocking juveniles to the sea, fin clipping (pelvic), painting, tattooing, and anchor tagging are all used to help identify the fish. Genetic markers are being tested to identify hatchery-reared individuals among wild population.

RAISING TO MARKETABLE SIZE

Wild juveniles as well as hatchery-reared juveniles are being used for seeds of red sea bream culture. The size of wild seed is 2.5–10.0 cm and its availability varies with location (April–August). Some farmers prefer wild juveniles to artificial ones' since the former is superior in stamina and activity to the latter. But, hatchery-reared seeds are well domesticated and easily start to feed after transportation and introduction into net cages for rearing.

For raising to marketable size, the net cage made of chemical fiber net is commonly used. Net cages are hung from a raft which shape is rectangular, octagonal' or circular. The rectangular cage is the most common, and the size of the cages are 4 x 4 x 4, 5 x 5 x 5, 6 x 6 x 5, and 8 x 8 x 6m with their actual volume, 50, 100, 150, and 300 m^3 respectively. The net is exchanged once per a month or two months (Fig. 10). The rafts are placed in inlets and small bays where it is calm, but with moderate currents to facililate the exchange of sea water in net cages. The rafts were initially made of bamboo, but steel pipes (ϕ, 50 mm) with a floatation factor of 200–250 kg are commonly used at present.

The density of fish in net cages is nearly 10 kg/m^3, and almost all of local government regulation recommend 7 kg/m^3 to aquaculturists, considering the possible sudden change of environmental condition such as red tide, shortage of oxygen, and increase of suspended matter in the water. Mesh of the nets varies along with the growth of the fish: 1.7 cm (30–75g, August to October), 3 cm (75–135g, October to April), and 4 cm (more than 135g).

Red sea bream prefer 20–28°C, and show active feeding and growth rates. The feeding behavior decreases below 20°C, and feeding stops at 10°C[3]. Feeding behavior of red sea bream tends to fluctuate at higher temperatures (more than 29°C), and physiological changes easily happen. Red sea bream shows a faster growth rate in the sea where water temperature seldom reach less than 13–14°C. Red sea bream has a strong tolerance to low salinity, and survive at the salinity of 16%. But, the feeding rate will decrease and physiological conditions tend to change at lower salinity. In view of oxygen consumption, 15ℓ of sea water should be supplied for a 500g red sea bream (in case of the dissolved oxygen 5 mℓ/ℓ). The desirable environmental conditions for red sea bream culture are as follows: 1) suitable water depth (more than 2 times the net cage depth), 2) moderate tidal current and high water exchange rate, 3) water temperature of 12–18°C (ideal minimum temperature is more than 13–14°C), 4) far from river mouths that supply fresh water and other contaminations' 5) calm bay or inlet to protect the cages against typhoon and stormy waves, 6) convenient locations for the supplies feeds, harvesting, and markets, 7) no red tide.

Red sea bream is sometimes harvested at the weight of 150g and sent to market, but the usual marketable size is more than 500–600g, with the most common marketable size about 1 kg. Therefore, it takes more than two years to raise red sea bream up to this marketable size. Usually, it takes 30 months for raising juveniles to a marketable size of 1 kg.

Raw fish (anchovy, sand eel, scomber, and horse mackerel) are commonly used to raise red sea bream. The food conversion ratio is 11.3 from 10g to 720g size range (16 months). The factor varies along with developmental stage, feeding method, and feeds, but is generally 5.1 in year one fish, 9.7 in year two fish. Formula feed is also used. It is convenient for transportation, storage, and for feeding additional supplements of vitamins and minerals, therefore its demand has been recently increased and the quality has been highly improved. Several companies supply formula feeds for red sea bream culture. The compositions of a commercial formula feed is: crude protein 45.0%, crude fat 3.0%, crude fiber 3.0%, calcium 1.8%, phosphate 1.2%, and a trace supplement of vitamin mix.

Japanese people prefer red sea bream with a deep red color. Therefore, the bream must be red before marketing and aquaculturists intensively feed krill and several species of shrimps for several weeks before harvesting. Krill and shrimps include high levels of astaxanthin. The red color of red sea bream is derived from the astaxanthin in the skin. A black cloth cover is used to cover the net cages and reduce illumination since strong sun-shine causes an increase in the melanin pigment in the skin of red sea bream.

The red sea bream shows a high tolerance to various kinds of disease, but several diseases have been reported. The main diseases are as follows: 1) viral disease (*Lymphocystis*), 2) bacterial disease (*Vibrio*, glinding bacteria, *Edwardsiella*), 3) parasitological disease (*Bivagina, Philometroides, Longicollum pagrosomi*), 4) others (dietary disease, yellow-fat disease)[37]. Among them, dietary disease is the most frequent (37%). The annual damage by various kinds of disease is nearly 2–3%, or approximately 650t. The most successful technique to prevent disease is based on prevention rather than fish therapeutics. Techniques of are as follows: 1) careful handling of fry in transportation, 2) careful and skillful technique for net cage change, 3) suitable population density in cages (the ideal density is less than 3 kg/cm^3), 4) daily observation with a keen eye and careful recording of feeding behaviour and amount. For treatment of fish disease with medicine, aquaculturist's consult with a disease specialist or with the national license who work at the prefectural fish disease centers or related organizations.

HARVESTING AND MARKETING

Almost all of red sea bream is harvested and marketed in live condition. Harvesting season is not fixed, and depends on demand of consumers. For transportation of live fish, cargo ship which provided chambers to accomodate fish were used initially, but trucks with a water chamber and oxygen supply apparatus are commonly used at present.

During transportation, the following items are considered: 1) amount of dissolved oxygen, 2) CO_2, 3) ammonia, 4) excrement. An adult red sea bream consumes 50–100 mℓ of O_2/kg/h in and inactive condition and 150–400 mℓ of O_2/kg/h for juveniles and youngs) when the amount of dissolved oxygen in approximately 5 mℓ/ℓ. The consumption varies with temperature and the duration of transportation, and the minimum limit for oxygen is 2.8–1.4 mℓ/ℓ for red sea bream to survive. Therefore, careful observation of oxygen in the chamber during transportation is important and additional supply of oxygen by oxygen tanks is required. CO_2 is easily dissolved into sea water, and is changed to carbonic acid. The acid decreases the pH value in the water, and CO_2 in the blood of fish is rarely released to the sea water. The reason why fish do not get enough oxygen in spite of enough oxygen in the water, is the decreased capacity for hemoglobin in the blood to extract oxygen from the water. Ammonia is harmful to fish, and, the excretion of ammonia should be controlled by decreasing the temperature. Prior to transportation, red sea bream are starved since feces and excrement contaminate the water. The period of starvation is 5–7 days in summer, 2–3 weeks in winter.

SUMMARY AND FUTURE EXPECTATIONS

In 1987, total production of the red sea bream was nearly 38,000 tons. The number of farmers who cultured the red sea bream in Japan was 2,909 in Japan. They used 19,451 net cages and 159.4 ha for the floating net cages. The production has steadly increased for the last ten years (Table 1). The total production will be increased in the future since approximately 65 million juveniles were introduced into cage nets in 1987. The cost for the production of a red sea bream (1 kg) is nearly 1,480 yen (10 U.S. dollars for three years raising) and the net profit is 568 yen (4 dollars) for one red sea bream in case of the successful culture. Thus, the industry of red sea bream culture has been successful because of the economical development in Japan and the industry will be further developed in the future. But, the following items should be considered to protect the industry: 1) carrying capacity in inlet and bay (too high a density of culture spoils the aquaculture sites), 2) pollution (improvement of feed and feeding method to conservate water quality, and bottom condition, 3) development of preperception and prevention for red tide, 4) disease (same as in red tide), 5) effective prevention of fouliva organisms on nets.

For the production of the red sea bream, technology for both juveniles and adult of marketable size has been well established. But, improvement of their quality are strongly required by consumers and farmers. Japanese think highly of color, shape, and flavor of fish, and wild red sea bream are usually superior in these points to cultured one and the former's market price is sometime twice that of the latter. Various kinds of studies to improve the quality of red sea bream have been conducted in Japan. These have been nutritional, genetic, and environmental approaches, respectively. Genetic improvement is intensively attempted at present in Japan.

Evaluation of the juvenile is also severe among farmers in Japan, and some farmers prefer wild juveniles to hatchery-reared one since the former is healthier, more active, and tolerant to disease and environmental change, though the hatchery-reared one is well acclimated to artificial conditions and smoothly starts the initial feeding in net cages. Therefore, improvement of the quality for hatchery-reared juveniles is important, and evaluation and comparison of the juveniles with various kinds of feeds and environmental conditions, in stamina and body contents, are important arears for fututre research.

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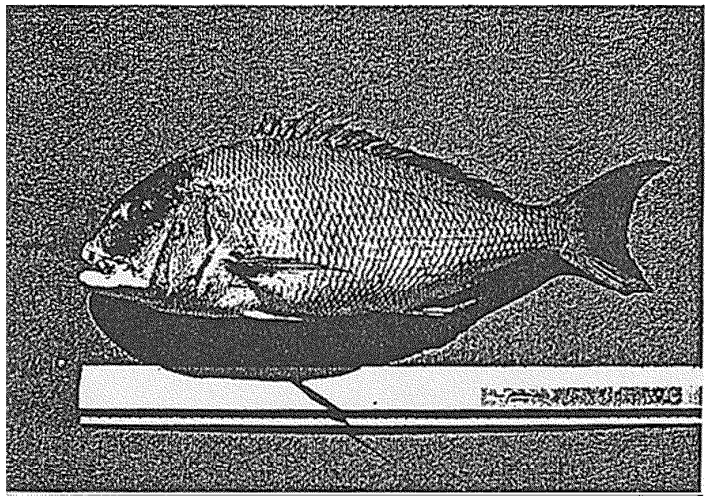

Fig. 1 Cultured red sea bream, *Pagrus major*.

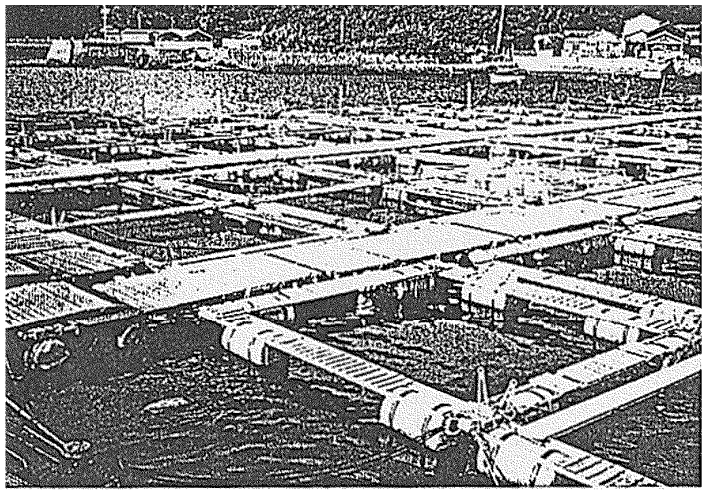

Fig. 2 Raft with net cages for red sea bream culture at the Ushibuka Station, Kumamoto Pref. Inst. Fish., Amakusa, Kyushu.

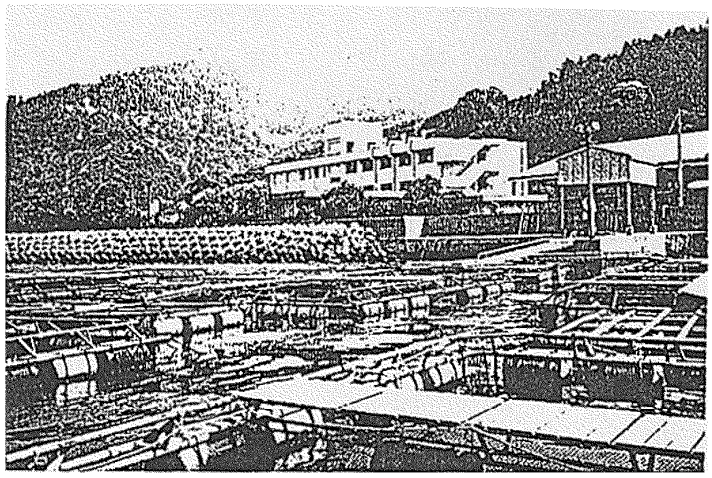

Fig. 3 Net cages for the brood stock of red sea bream at the Ehime Pref. Inst. Uwajima, Shikoku.

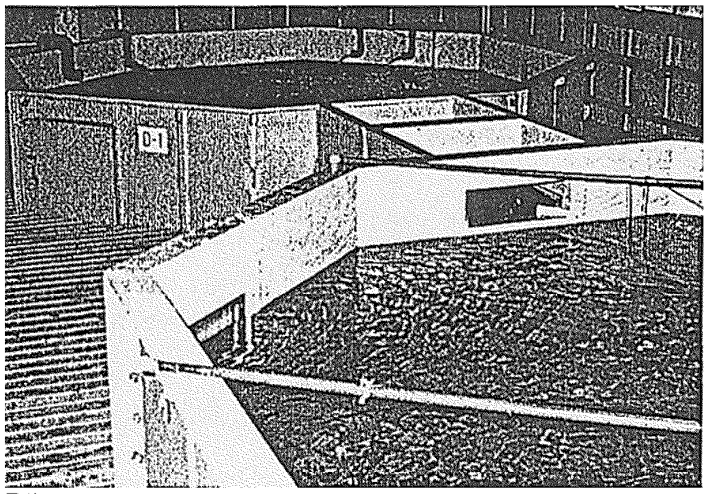

Fig. 4 Land based tanks with sand filter and circulation for the brood stock of red sea bream at the National Res. Inst. of Aquaculture, Nansei, Mie Pref.

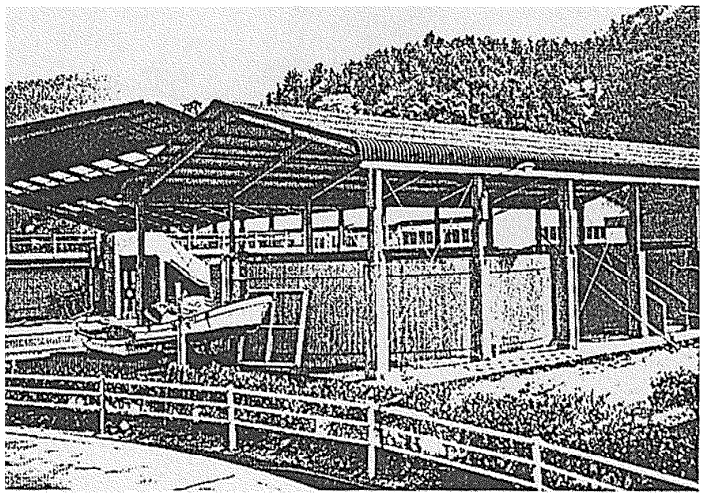

Fig. 5 Land based tank for natural spawning of red sea bream at the Ehime Pref. Fish Farming Center, Uwajima, Shikoku.

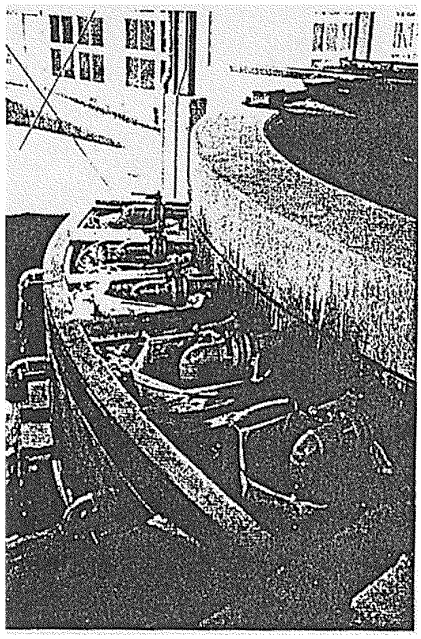

Fig. 6 Apparatus for the collection of buoyant and fertilized eggs at the Ehime Pref. Fish Farming Center, Uwajima, Shikoku.

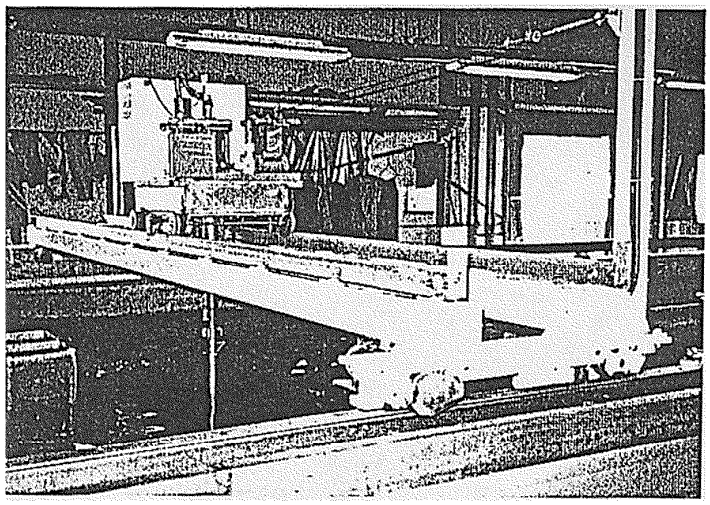

Fig. 8 Larval rearing tanks (100 m^3) with automatic bottom sweeper to remove sediment at the Mie Pref. Fish Farming Center, Hamajima, Mie.

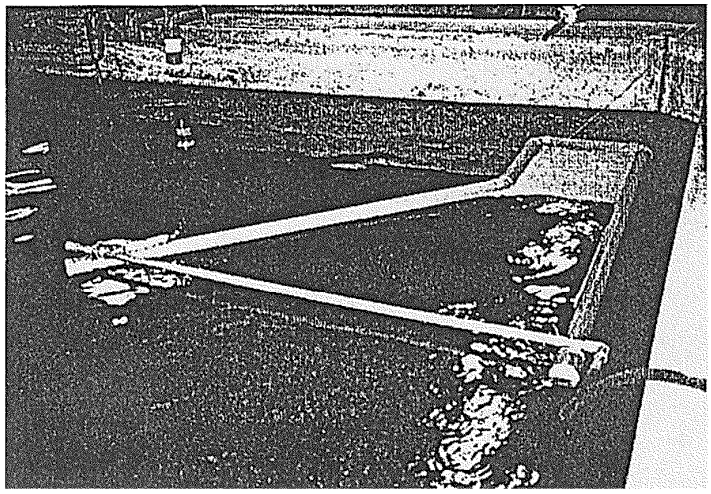

Fig. 9 A simple equipment with air blower to clean the water surface for air to dissolve into water, and to avoid the production of juveniles with lordosis. Wind from the small pores on the floating pipe blows and concentrate oil membrane to the corner of the equipment and condensed oil membrane is timely removed by a hand net.

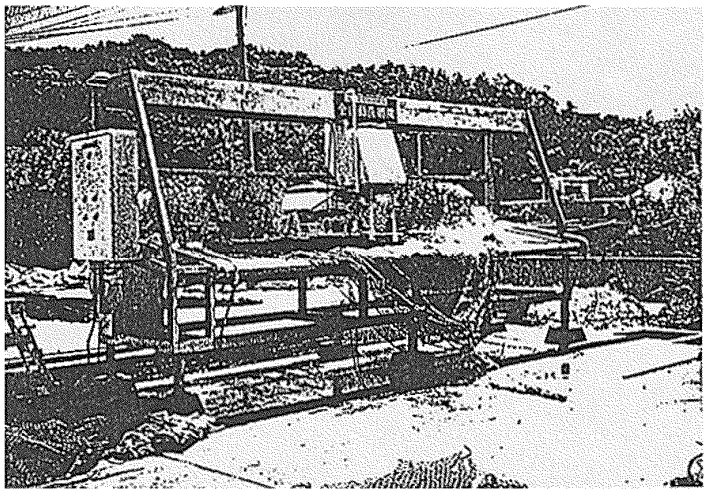

Fig. 10 Automatic cleaner of cage net, at the Mariculture Lab., Nagasaki Pref. Inst. of Fish., Nomozaki, Kyushu.